Roadblocks: Current Technology Challenges for Ubiquitous Virtual Reality

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Abstract

Ubiquitous Virtual Reality is a very young field of research investigations. The interdisciplinary nature of research in Ubiquitous Virtual Reality is built on the combination and leveraging of a number of technologies to create revolutionary interactive graphical information systems that may be exploited on a universal scale. This paper presents a number of current technology challenges for *Ubiquitous Virtual Reality*. There are four challenging areas of technology that will be discussed in this paper: mobility, interaction, attention, and reactivity.

1. Introduction

Ubiquitous Virtual Reality (U-VR) [1] appears to be a contradiction when one first comes upon the concept. After all Virtual Reality (VR) [2] is concerned with completely replacing real world stimulus to a user's perceptual system with artificial stimulus. The most common stimulus is visual, and this is replaced via display technologies such as a head mounted display (HMD) or projectors as in a CAVE. The second most common stimulus is audio, which is replaced by a 3D audio system. VR has explored replacing tactile, haptic, olfactory, temperature, and taste. In the movie "The Matrix", all perception was replaced directly through the nervous system. VR stimulates the user's own perceptual system, i.e. eyes, ears, and such, through the use of technologies external to the user's body. By its very nature, VR systems require the user to be restricted to a fixed location. The HMD is unsafe to use outside a confined area, and a CAVE is a fixed space physical structure.

The essence of U-VR is not turning the whole physical world into a virtual world. The point of U-VR is to take the key useful features of VR and transform them into useful technologies that are accessible in everyday life. Ubiquitous Virtual Reality is an interdisciplinary research field, covering such domains as: Virtual Reality, Mixed Reality [3], Augmented Reality [4], Wearable Computing [5], Pervasive Computing, Ubiquitous Computing [6], Haptic Interfaces, Mobile Context-Aware Computing [7], Emotional Affective Agents, Computer Vision [8], Sensors, Intelligent Systems, Human Computer Interaction [9], and Computer Graphics [10]. U-VR combines and leverages these technologies to create revolutionary interactive graphical information systems that may be exploited on a universal scale. U-VR attempts to answer the question:

What if high quality intuitive graphical information was available in a ubiquitous manner?

This paper will outline a number of current technology challenges for U-VR. There are four challenging areas of technology that will be discussed in this paper: *mobility*, *interaction*, *attention*, and *reactivity*. Table 1 maps the interdisciplinary domains onto these four challenging areas of technologies. There is not room in the paper to explore all aspects of this table, but each of these four areas of technology will be described through a subset of the specified domains.

2. Mobility

The *mobility* of the user is paramount for the usefulness of U-VR. The user must be able move through their normal activities without the hindrance of technologies. This may be achieved by miniaturizing the technology to be worn, as with wearable computing [11]. A second approach is to embed the technology into the environment as with

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ubiquitous computing. The most appropriate tactic is to combine both [12], and apply the correct technology when required. This section will explore a number of current technology challenges facing this combined approach.

Social acceptability is a critical factor for the use of these technologies in the general public [11]. The current wearable computers with a reasonable computing and graphical capability are extremely bulky for consumer use. The current state-of-the-art 3D graphical wearable computer system is Tinmith [13], which is presently ~4.5 Kg and is belt worn. The use of head mounted displays adds to the mobility, but is not very well received by users. In the near future, small garment [14] or phone/handheld [15] based systems will be more commonplace.

I feel the critical factor is the visual effect of the computing system on the user's fashion sense having the greatest impact. People are quite willing to carry heavy notebook computers with them in traditional backpacks or over the shoulder bags. The current user has the desire to have their computing needs at their finger tips at all times, but they do not wish to have the technology define how they look. Therefore computing resources will need to fit within the current persons clothing, artifacts, and surroundings. A number of possible items of technology that could solve these issues:

1. Head mounted displays that are the same size and shape as traditional eyewear.
2. Notebook level of computation and graphics within a single handheld device.
3. Pervasive networking to allow the user to reduce the processing power they have to carry.
4. Lightweight wireless display panels that are either carried or ubiquitously placed in the environment.

3. Interaction

The user's ability to interact with high quality graphical information is extremely important. Clearly traditional workstation input devices such as a mouse or a keyboard are not suitable for all tasks within U-VR. These input devices are very much unsuitable for the mobile use of U-VR. This highlights two main issues for interaction while the user is mobile and they are interacting with virtual data.

Current highly mobile systems, such as mobile phones, have interfaces that are optimized and customized for particular functionalities, such as talking. To perform interactions with virtual data while the user is mobile requires a new set of input devices. A major challenge is providing interaction technologies for the wide range of information presentations required in future U-VR systems.

One option is a generic interaction technology, such as Star Trek Tricoder. Wloka and Greenfield developed the "Virtual Tricorder: A Uniform Interface for Virtual Reality" [16]. The Virtual Tricoder handheld device virtually changes shape and options for the required function on hand. This epitomises the concept of a generic input device, one-size-its-all. Traditionally virtual environments have supported generic input devices to maximize the functionality of what would be an expensive piece of infrastructure. The notable exceptions to this rule have been training simulators, such as for flying, medical procedures, or fire fighting. These are highly specialized single purpose systems, but are inappropriate for U-VR.

U-VR requires a set of radically different input devices for all the different forms of virtual information supplied to the user. Information supplied in a visual augmented reality form might require much different interaction techniques than that supplied by emotional affective agents. I envision a wide array of user interaction tools for the end user in a full-scale U-VR system. Tools are required to support activities such as the following: text entry, pointing, gathering, bundling, copying, duplicating, painting, and tagging. These techniques are required across a wide range of forms of information, emotional, visual, audio, physical, spatial, tactile, and temporal. The challenge is the supply of these tools without on one hand making a "Swiss army knife" and on the other hand having the user lug an auto mechanics full toolbox. One possible solution is to make sure many of these tools are already in the environment when the user requires them.

4. Attention

A key to keeping the systems useful is the control of how the systems influences the user's attention [17]. Burdening the user with additional alerts, buzzers, and ring-tones will only make the use of U-VR impossible. U-VR, by its very nature, requires the full attention of the user at key moments. This section will explore the important challenges to achieve this balance.

Figure 1 depicts an example of overloading the visual senses of the user. This is the graphical overlay of ARQuake [18]. As one can see, the virtual information overwhelms the user's view of the physical world. In fact this form of interface may cause "information tunneling," when a user focuses on the virtual information and not the physical world. In the case of the game, this may endanger the player by inhibiting their ability to sense dangers in the physical world. This example shows clearly how the overlaying of information may disrupt the user's ability to operate in the physical world.

Figure 1. Example of overloading with AR

Figure 2 depicts a simpler interface for the user. In this example the user is directed to the machine shop. The cognitive load in understanding the interface is much lower. Keeping the information simple and essential is the key to making augmented and mixed reality interface understandable. This is achieved by only displaying essential information and leaving out the rest. The fundamental of displaying information in AR is "less is more". The simple red line on the ground and the highlighting of the doors provide good cuing to the user. The complexity interface in Figure 2 could be further reduced by removing the menu on the bottom of the screen, the blue compass, and the green lines. This concept needs to be extended to all forms of U-VR information.

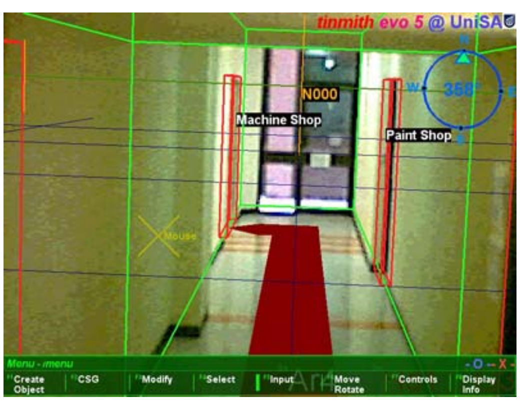

Figure 2. A simpiler AR interface

5. Reactivity

The ability to be reactive is the key to the following research domains in U-VR: pervasive computing, ubiquitous computing, haptic interfaces, mobile context-aware computing, emotional affective agents, computer vision, sensors, and intelligent systems. A key challenge for U-VR is the ability to understand and react to the environment, the user's needs, and current ambient activities. This section will explore the key open challenges in making U-VR systems understand and react to demands made upon them.

A major challenge is the understanding of the world around the user. For contextual computer interfaces to work, they require a good knowledge of the user's current environment (physical, social, virtual, and so on). To obtain this knowledge the environment needs to be sensed and understood. There is a wide array of possibilities to gain this knowledge, and choosing the correct subset is essential for proper understanding and constraints of the problem. The choice of possibilities for the system sense and understand is very much a current open research question in understanding the user's context. Once the system understands the context, then proper reactions need to be developed for the user. Research areas such as model based reasoning, configuration management and constraint systems will be required.

6. Conclusion

In conclusion this paper presents an overview of a number technical issues facing Ubiquitous Virtual Reality. In particular, the paper focused on four challenging areas for technology: mobility, interaction, attention, and reactivity. The paper discussed a number of potential roadblocks and hypothesised on possible technology solutions.

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Domains	**Mobility**	**Interaction**	**Attention**	**Reactivity**
Virtual Reality		X	X	
Mixed Reality		X	X	
Augmented Reality	X	X	X	
Wearable Computing	X	X	X	
Pervasive Computing		X	X	X
Ubiquitous Computing		X	X	X
Haptic Interfaces		X		X
Mobile Context-Aware Computing	X	X	X	X
Emotional Affective Agents			X	X
Computer Vision				X
Sensors				X
Intelligent Systems				X
Human Computer Interaction		X		
*C*omputer Graphics			X	

Table 1. Mapping of technology concerns to U-VR interdisciplinary domains